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DREO TECHNICAL NOTE NO. 78-3
DREO TN 78-3

THE AIRI FUSION CAST LEAD CHLORIDE ELECTRODE
PART II
EVALUATION OF THE CATHODE FOR
AN EIGHT HOUR SONOBUOY BATTERY

by

G.J. Donaldson and W.D. Barnes

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JUN 13 1978

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PROJECT NO.
54-03-07

APRIL 1978
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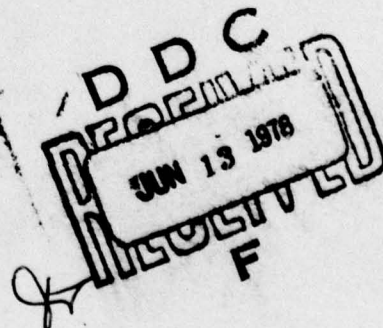## TECHNICAL NOTE NO. 78-3

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ABSTRACT

The AIRI lead chloride cathode was evaluated for an eight-hour sonobuoy battery application. Tests on ten-cell batteries resulted in only five to six hours of discharge for electrodes capable of meeting the rigorous activation criteria in low temperature, low salinity seawater. Cathodic efficiencies between 75% and 95% were obtained and no deterioration in electrical performance was detected as a result of a ten day humid storage period. To achieve the goal of eight hours discharge it is recommended that AIRI cathode be fabricated using an expanded metal rather than a woven screen.

RÉSUMÉ

L'électrode au chlorure de plomb AIRI a été évaluée en vue d'être utilisée pour alimenter une bouée acoustique pendant huit heures. Les piles de dix cellules qui satisfaisaient à des exigences d'activation rigoureuses en conditions de basse température et de faible salinité avaient une durée utile de cinq ou six heures. Les rendements cathodiques variaient entre 75% et 95%, et aucune diminution du rendement en électricité n'a été notée après un stockage préalable d'une durée de 10 jours en conditions humides. Afin d'augmenter la durée de décharge jusqu'à huit heures, on propose de préparer la cathode AIRI à partir d'un métal expansé plutôt qu'à l'aide d'une grille tissée.

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INTRODUCTION

BACKGROUND OF LEAD CHLORIDE ELECTRODE DEVELOPMENT

Research and development on lead chloride has been actively pursued by DREO since 1969 with the basic objective of replacing silver chloride in water activated batteries. Coleman reported a technique which consisted of hot pressing a mixture of lead chloride, powdered lead and graphite. (1,2).

The Atlantic Industrial Research Institute (AIRI) pioneered a distinctly different method for making a flexible lead chloride cathode. Theirs was essentially a fusion casting process whereby a metallic grid was immersed in molten lead chloride followed by solidification in air. From 1971-1976 DREO sponsored the AIRI work through a series of research and development contracts on different forms of lead chloride electrode for sea-water batteries (3). This has culminated in an improved production technology for making lead chloride cathodes. In the final contract year AIRI was commissioned to develop its production equipment and manufacturing techniques for the fabrication of flexible electrodes at a level needed for full scale industrial use. The annual Canadian requirement is for a quantity of electrode material to manufacture twenty-five thousand sonobuoy batteries. AIRI was asked to produce electrodes capable of eight hours discharge at the typical sonobuoy battery rate.

The progress achieved by AIRI in the final phase of this work was reported at the end of the contract (4). A semi-automatic machine process was developed and proved capable of meeting the specified industrial scale of production. It was also shown how electrode material having a range of electrical capacity could be made. This was demonstrated publicly at the AIRI laboratories 19 February 1976 to representatives from more than twenty Canadian companies and several government departments. Two patent applications have been filed on this technology both in Canada and the United States.

SUMMARY OF PREVIOUS STUDY

Through most of the contract period the electrochemical performance of the AIRI flexible electrode has been studied at DREO. A preliminary evaluation of this material for use in sonobuoy batteries was reported recently

and constitutes the first part of the overall evaluation (5). It was determined that the AIRI electrode gave electrical performance in excess of the specifications for a three hour battery. It was shown that for rapid activation in low temperature and low salinity seawater the material had to be carefully selected according to the weight content (or loading) of lead chloride. Specifically, the loading had to be sufficiently light and uniform so that the underlying copper grid was exposed at the electrode surface. Although most of the study had been done using eleven cell $Mg/PbCl_2$ batteries it was evident that ten cells could adequately meet the output requirement of 10 volts. The fact that the electrode is flexible is incidental to the sonobuoy battery application which uses planar cathodes. An earlier requirement for a spirally wound $Mg/PbCl_2$ battery gave rise to the initial interest in the AIRI process; however that requirement has since ceased to exist.

OBJECTIVES OF THE PRESENT WORK

This technical note is Part II of the evaluation of the AIRI electrode for a sonobuoy battery application. It addresses the problem of developing a battery using the AIRI cathode which can be discharged for up to eight hours. Some changes in battery design were investigated in order to decrease intercell shorting, thereby increasing overall discharge efficiency. Part II of the study has been necessarily delayed because it relied on obtaining the final product of the process being developed by AIRI. It should be noted that in the evaluation of the AIRI electrode only the electrical performance of the main battery was investigated. No work was done to test for the effects of shock and vibration or other testing procedures usually carried out by sonobuoy manufacturers.

EXPERIMENTAL

CRITERIA FOR EVALUATING THE AIRI CATHODE

For assessing the electrochemical performance of the AIRI lead chloride electrode the electrical specifications given for the SSQ517A sonobuoy battery were used for guidance. Nominally, the battery output is 10.1 volts with upper and lower limits of 10.9 volts and 9.6 volts, respectively. The length of discharge was therefore taken as the time after activation when

output fell to 9.60 volts. Batteries were discharged in artificial seawater
of concentrations 1.5% and 3.6% (by weight NaCl) at the following temperatures:
0°, 12°, 20° and 35° C. When tested at 0° and 35° the batteries were first
brought to thermal equilibrium overnight at -20° and 35°, respectively.
Discharges were subsequently initiated within one or two minutes of removing
the batteries from a thermally regulated chamber. For activation the criterion
was the ability of the battery to blow two fuses in the electrical test circuit
which is shown schematically in figure 1. The efficacy of this particular test
was described before in Part I(5). For the present work sixty seconds was
accepted as the time limit for activation.

CATHODE MATERIAL

The process developed by AIRI for making the flexible lead chloride
electrode is a semi-automatic machine operation. The schematic diagram is
given in figure 2. A copper screen or gauze is fed from a large spool and
guided through a thermally controlled bath containing molten lead chloride.
As the strip emerges from the melt a deposit of lead chloride is formed by
solidification in the cooler air above the chamber. The electrode tape is then
fed between two water-cooled rollers and may then be taken up on a spool or cut
to electrode size by another operation. The amount of lead chloride deposited on
the metal substrate is a function of several variables of which the most important
are: the properties of the metal grid, the speed of passage through the molten
salt, the rate of cooling, the melt temperature and the angle at which the
material emerges from the melt. Immediately on leaving the melt the electrode
material is passed through a slit which serves to prevent any scum which may
be present on the surface of the melt from sticking to the deposit.

During the stages of process development there was a gradual improvement
in the quality of electrode material and several shipments were sent to DREO
for electrochemical evaluation. Towards the end of the contract the AIRI
product was in the form of strips approximately 60 cm long by 11.5 cm wide.
The last delivery, made in May 1976, contained some of the best quality of
electrode made by the process. Different sizes of woven copper screen had been
used during the development of the production machine. A 20 x 20 mesh size
was found to yield the best electrode considering the quality of the surface
and the quantity of lead chloride deposited. The last batch of product was on
the 20 x 20 mesh and consisted of a large variety of loadings from less than
100 mg cm^{-2} to more than 600 mg cm^{-2} of PbCl$_2$. In general the surface of the
electrode was greyish for the heavier deposit and pink for light coatings.
The material was flexible, but the deposit could be loosened by continually
bending it back and forth. In most of the samples there was good uniformity
of loading, there being less than about five percent variation in lead chloride
content for the material employed in the present study.

For making sonobuoy batteries which must achieve rapid activation
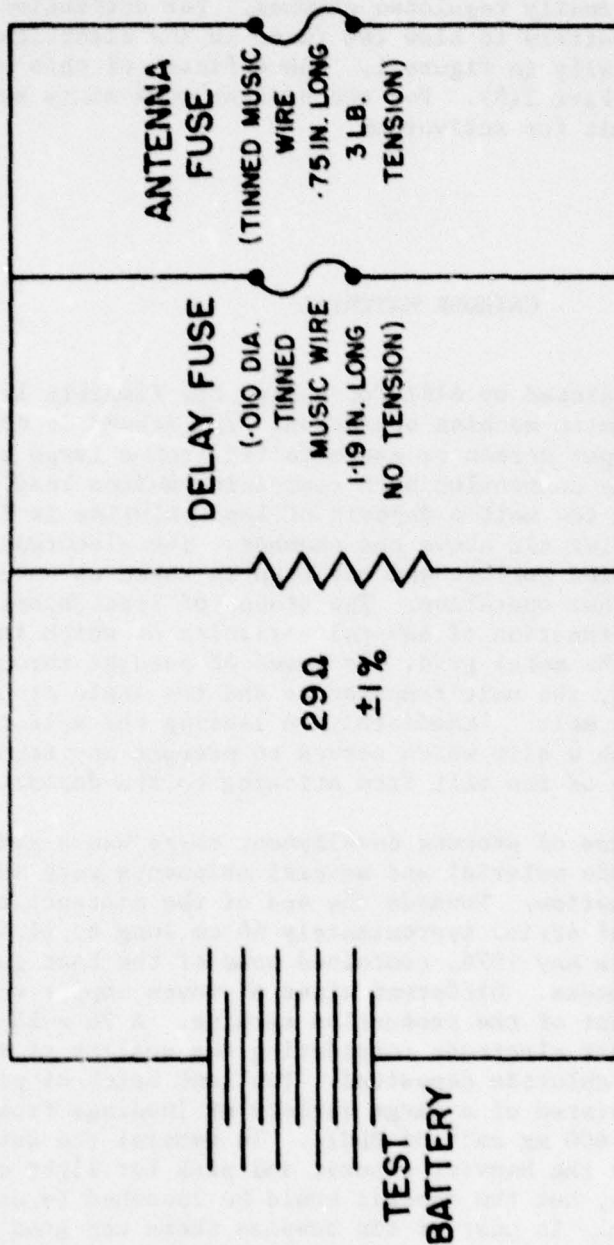in low-temperature, low-salinity seawater only a medium-light electrode

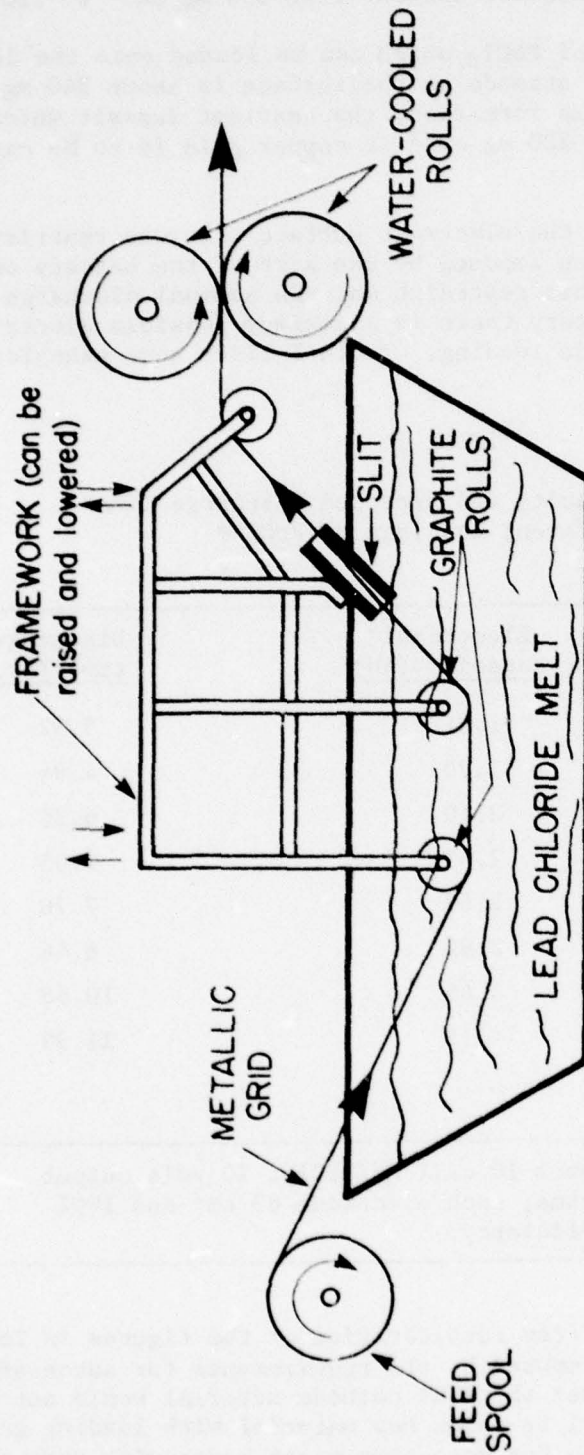*Fig. 1: Schematic diagram of test circuit for discharging seawater-activated Mg/PbCl₂ batteries.*

Fig. 2: Schematic diagram of machine developed by AIPI for fabrication of flexible PbCl₂ electrode material.

coating can be used (5). For the present study the material was therefore chosen in the range of lead chloride content from 140 mg cm^{-2} to 220 mg cm^{-2}.

The maximum amount of $PbCl_2$ which can be loaded onto the 20 x 20 grid without coating over the strands at the surface is about 340 mg cm^{-2}. However, due mainly to meniscus formation, the heaviest deposit which can be obtained in practice is about 220 mg cm^{-2} if copper grid is to be exposed on the surface.

In the present work the electrode surface area was restricted to 63 cm^2, this being a limitation imposed by the size of the battery compartment in the sonobuoy (5). Given this restraint and the nominal discharge characteristics for the 10-cell battery there is a maximum possible electrical capacity depending on electrode loading. Table I lists some examples.

TABLE I

Electrical Capacity and Expected Discharge Time
for Different Loadings of $PbCl_2$*

$PbCl_2$ Content of electrode (mg cm^{-2})	Electrical capacity (Ah)	Discharge time (hr.)
100	1.21	3.52
140	1.70	4.94
180	2.19	6.35
200	2.43	7.05
220	2.67	7.76
240	2.92	8.46
300	3.65	10.58
340	4.13	11.99

* NOTE: Table I assumes 10 cell Mg/$PbCl_2$, 10 volt output through 29 ohms, each electrode 63 cm^2 and 100% discharge efficiency.

It becomes apparent from consideration of the figures in Table I and the various restrictions imposed by the requirements for successful activation and battery size that the AIRI cathode material would not produce an eight hour battery. It will be shown how material with loading greater than 220 mg cm^{-2} does discharge for more than eight hours with some sacrifice for meeting rapid activation. Nevertheless the results presented here show some

improvement over those given earlier in that better cathode utilization was achieved. It was considered worthwhile to report these results to complete the electrochemical evaluation of the AIRI electrode.

CONSTRUCTION OF TEST BATTERIES

Two sets of ten-cell batteries were employed; these differed only in the choice of anode material. One set of test batteries was made with the magnesium alloy AZ61 (6% Al, 1% Zn) the other set with AZ31 (3% Al, 1% Zn). It was of interest to examine both alloys because they are used in batteries which are now commercially available. In all cases a large excess of anode was used so that the discharge was limited by the electrical capacity of the cathode.

Bipolar cells were assembled from magnesium alloy and lead chloride material cut to the same size: 8.3 cm wide by 7.6 cm high; area = 63 cm^2. The anode and cathode were placed back-to-back on either side of a thin plastic sheet measuring 9.0 cm wide by 10.2 cm high. Passing through the centre of each electrode and the plastic was a brass rivet which served to keep the pieces fixed in position and acted as the electrical connection between adjacent cells. On the cathode side the rivet was coated with a fast-drying epoxy cement. Spacers were glued to the anode in a 5 x 5 array. These were small plastic chips, 0.1 cm thick and about 0.2 cm square. Ten such bipolar cells were stacked to form the test battery and electrical leads were soldered to the negative (magnesium alloy) and positive (lead chloride) end plates.

During the course of the work it became evident that greater precautions were required in assembling the batteries. The cell stack was carefully wrapped with a strip of insulation tape* equal in width to the thickness of the battery. This was done to provide better electrical insulation and therefore decrease the leakage path through the electrolyte around the edge of the electrodes. This is known to affect the efficiency of electrode utilization by reducing intercell shorting (6). Each battery was given a final wrapping with 2.5 cm wide plastic tape. Figure 3 shows the essential details of cell construction and battery assembly (reproduced from reference 5).

To provide a path for the flow of electrolyte between cells, holes (0.5 cm diameter) were drilled through the plastic sheet of each bipolar cell. In a series of experiments the arrangement of these electrolyte ports was varied in order to select an optimum design for porting consistent with:

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* This contains a bituminous substance and is about 0.3 cm thick, commonly used for covering hot or cold water pipes and refrigeration coils. It has the trade name "Presstite".

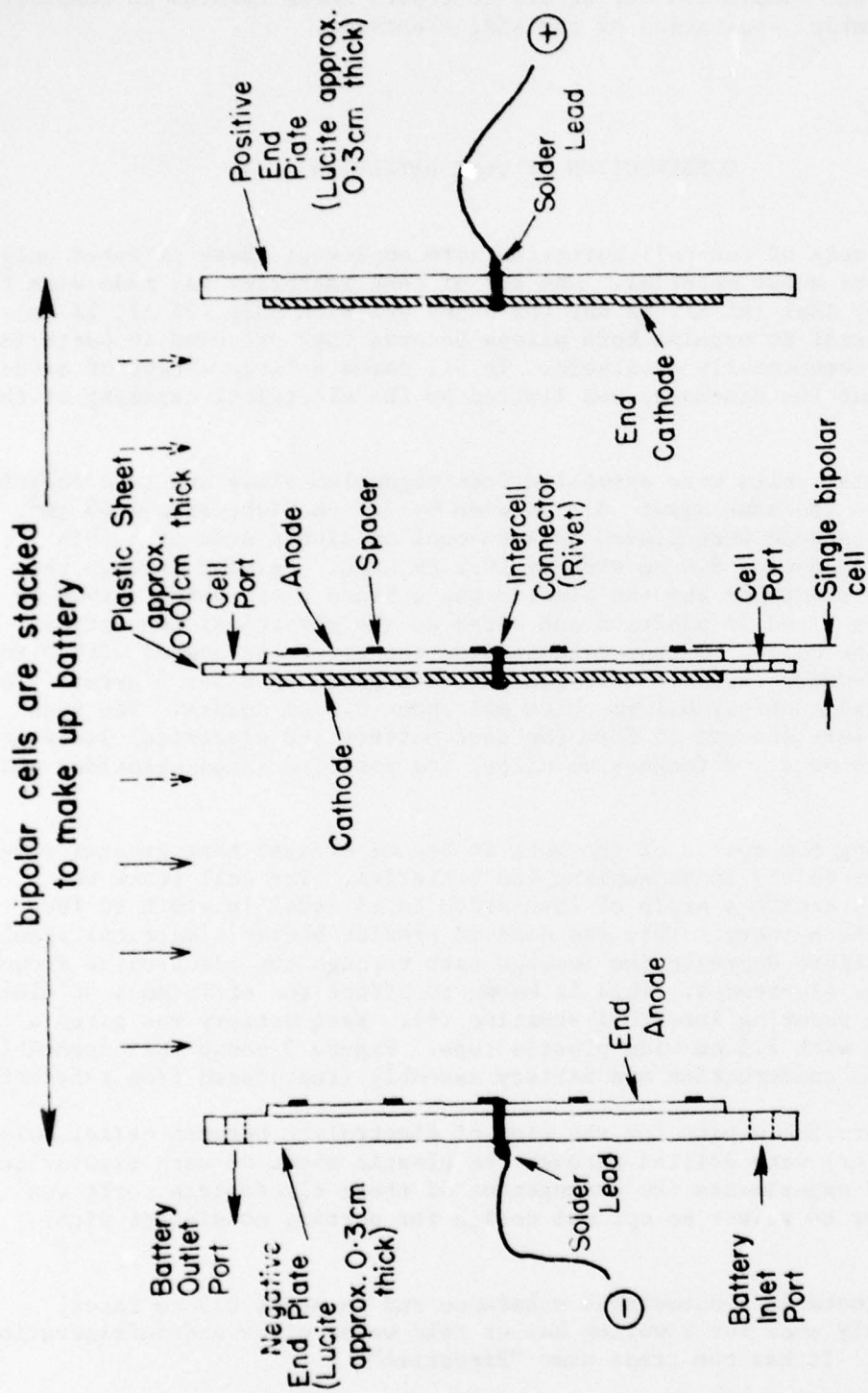*Fig. 3: Schematic diagram of construction of multi-cell Mg/PbCl₂ battery. (Reproduced from reference 5, Figure 2.)*

(a) rapid flooding of the battery interior when immersed in the electrolyte,

(b) adequate flow of electrolyte from cell to cell throughout the battery to avoid the accumulation of reaction products (i.e. "sludge", mainly $Mg(OH)_2$ produced by corrosion at the anode); and

(c) reducing intercell shorting via the common electrolyte path between cells.

Before assembly all cathodes were weighed to permit calculation of the theoretical capacity based upon the lead chloride content of the cell having the minimum weight. The relevant factor is 0.193 Ah capacity per gram lead chloride. A typical ten-cell $Mg/PbCl_2$ battery consisted of the following amounts of material:

TABLE II

Material Content Typical of 10 Cell $Mg/PbCl_2$ Battery

		Percent of Total Battery Weight
1. The Cathodes		
a) total weight of 10 electrodes	229.5 g	55.9%
i) copper content	104.4 g	
ii) $PbCl_2$ content	125.1 g	
2. The Anodes		
a) total weight of 10, AZ61 electrodes (0.05 cm thick)	55.6 g	13.5%
3. Packaging Materials (including intercell spacers, plastic sheets in each bipolar cell, rivets, plastic tape, insulation tape).	125.4 g	30.6%
Total Battery (without external leads)	410.5 g	100.0%

Outside dimensions were:

height	10.4 ± 0.2 cm
width	9.2 ± 0.2 cm
thickness	3.5 ± 0.2 cm

This battery was designed to fit inside the SSQ517A sonobuoy compartment, a cylinder 10.2 cm in diameter, but was slightly larger than the permitted height of 8.9 cm. Future design could be altered to meet the specification, but a larger battery compartment would probably be allowed for an eight hour battery. In the present form, for example, the electrodes cleared the bottom of the battery compartment by 1 cm and were 1.5 cm below the top. A reduction of overall height could conceivably be made to 8.9 cm without affecting the overall electrical performance.

DISCHARGE PROCEDURES

The test battery was mounted vertically in a compartment obtained from an AN/SSQ517A sonobuoy and its negative terminal was grounded to the aluminum casing. The test circuit of figure 1 was connected and the battery was then immersed into a thermally controlled electrolyte bath of 92 ℓ of the required concentration, 1.5% or 3.6% by weight sodium chloride (reagent grade salt).

Battery output was monitored continuously on a stripchart recorder, Hewlett-Packard, model 7100B, and the time and voltage simultaneously printed using a Monitor Labs, model 9400 data acquisition unit. For the first two minutes data were printed at one second intervals, thereafter at five minute intervals. All measurements generally were terminated after battery output fell below 9 volts.

Two batteries, one with each of the two different magnesium alloys, were subjected to ten days humid storage before discharge in 3.6% seawater at $12^{o}C$. The following daily programme of temperature and humidity cycling was carried out in an environmental chamber (Tenney Engineering Inc., model TH Jr.):

    i)   7 hours at $50^{o}C$, 95% Relative Humidity (RH),

then ii)   3 hours cooling from $50^{o}C$ to $35^{o}C$, R.H. not less than 95%,

then iii)   14 hours at $35^{o}C$, 95% R.H.

Each battery was weighed before and after the ten day humid storage period. While in storage the electrical leads were connected across a 29 ohm resistance. If the battery were to pick up excess moisture or for some other reason develop internal shorts, a significant loss of capacity would occur and be detected in the subsequent discharge.

RESULTS AND DISCUSSION

DISCHARGE EFFICIENCY OF CATHODE UTILIZATION

It was noted in the results of Part I (5) that batteries employing the AIRI cathode yielded only about 70% cathode utilization. However, in that work no special precautions were taken to minimize intercell shorting. It was decided to improve cathode utilization in the present study in part because the electrode material suitable for meeting the demanding activation requirements was limited in electrical capacity. Although it was obvious that an eight hour battery was not going to be achieved it was nonetheless desirable to determine whether the AIRI cathode could be discharged with high enough efficiency to make further developmental work worthwhile.

To estimate the best possible cathode utilization several $Mg/PbCl_2$ cells were discharged. The experiments were done in 1 ℓ of 3.6% NaCl at $24^{\circ} \pm 2^{\circ}C$ using a constant load, 2.63 ohm. The theoretical capacity was calculated from the known weight of $PbCl_2$ in the cathode, assuming high purity of the active material. The charge obtained from cell discharge was calculated by integration of voltage-time curves.

Some results typical of these experiments are given in Table III.

TABLE III

Constant Load (2.63Ω) Discharge of
$Mg(AZ61)/PbCl_2$ in 3.6% NaCl, $22^{\circ}-26^{\circ}C$

TIME (hr)	CELL EMF (Volts)	ACCUMULATED CHARGE (Ah)	PERCENT OF THEORETICAL CAPACITY (%)
0.08	1.05	0.03	1.3
.1.0	1.06	0.40	15.2
2.0	1.05	0.80	30.4
3.0	1.05	1.20	45.4
4.0	1.04	1.60	60.5
5.0	1.04	2.00	75.6
5.77	1.00	2.28	86.4

TIME (hr)	CELL EMF (Volts)	ACCUMULATED CHARGE (Ah)	PERCENT OF THEORETICAL CAPACITY (%)
5.90	0.96*	2.34	88.6
6.04	0.90	2.39	90.5
6.31	0.87**	2.48	93.9
6.62	0.80	2.58	97.7
6.85	0.40	2.64	100.0

*   The appropriate cut-off voltage for 1/10 of a 10-cell battery.

** The appropriate cut-off voltage for 1/11 of an 11-cell battery.

During most of the discharge the current density for this cathode was about 6.4 mAcm^{-2}, which is the rate normally employed for a sonobuoy battery. These and similar data indicated that essentially all the theoretical capacity is obtainable from the AIRI cathode. It is therefore fairly certain that the active material is of acceptably high purity. Once cell output begins decreasing at a rapid rate (e.g. 0.03 volts/min) the data indicate that about 97% of theoretical capacity has been delivered. However, the appropriate cut-off voltage (see Table III) occurs somewhat before this, depending on temperature, salinity and discharge rate. The data in Table III suggests a reasonable expectation for cathode utilization is in the range 85% to 95%.

In the course of these experiments it was found that impurities from the water used for preparing electrolyte were responsible for a significant decrease in cell voltage. Therefore experimental work was done using distilled water in order to eliminate factors of unknown origin which might bear on cathode utilization and other results.

Following from the results of cell discharges discussed above other experiments were carried out to test the effectiveness of various porting arrangements in an attempt to obtain better utilization of cathode material in ten-cell batteries. The best design was found to be one in which the electrolyte enters the battery from the negative end via a port centred at the bottom and leaves through a similar port at the top corner. This is shown schematically in figure 4. Such a design was most effective because:

1. it permitted rapid flooding of all cells,

2. there was less accumulation of sludge,

3. the utilization of cathode material was much better than the 70% reported earlier (5),
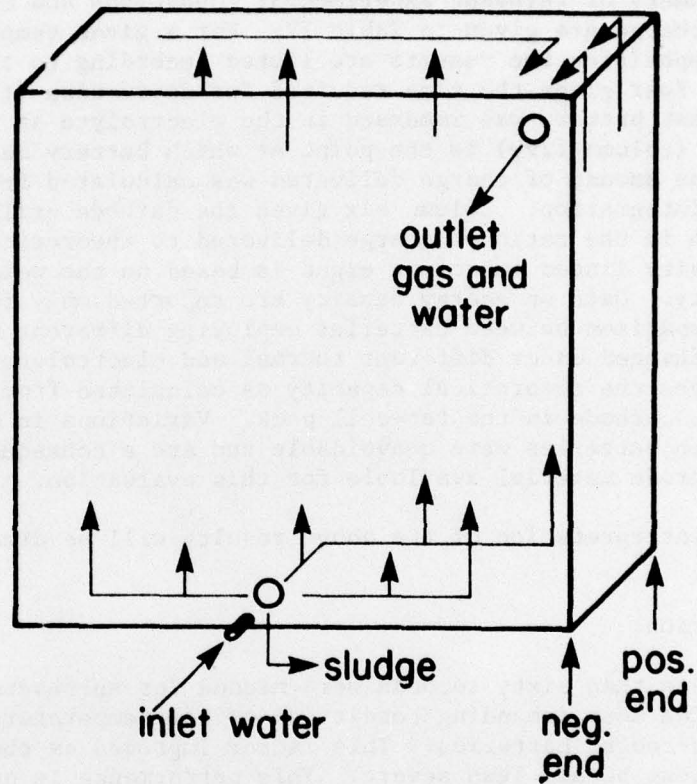
and 4. batteries were easy to assemble.

Fig. 4: *Porting arrangement indicating general*
pattern for electrolyte flow through
battery.

TEN-CELL BATTERY PERFORMANCE

A summary of relevant experimental conditions and certain features of battery discharge are given in Table IV. For a given temperature and electrolyte composition the results are listed according to the magnesium alloy. Column four gives the time required for activation (i.e. to blow both fuses). The test battery was immersed in the electrolyte at time t = 0. The discharge time (column five) is the point at which battery output fell below 9.60 volts. The amount of charge delivered was calculated from the voltage-time curve by integration. Column six gives the cathode utilization (as a per cent) which is the ratio of charge delivered to theoretical capacity. The energy density listed in column eight is based on the weight of the complete battery. Data on energy density are reported only for purposes of internal comparison between batteries employing different magnesium alloys and discharged under different thermal and electrolyte conditions. The last column gives the theoretical capacity as calculated from the known weight of the lightest cathode in the ten-cell pack. Variations in theoretical capacity between batteries were unavoidable and are a consequence of variability of electrode material available for this evaluation.

The interpretation of the above results will be discussed in point form.

(a) Activation:

Less than sixty seconds were needed for successful activation under the most demanding conditions of low temperature, low salinity and pre-cooled batteries. This factor improved as the experimental conditions became less severe. This performance is quite acceptable for a three hour sonobuoy battery; however activation would be slower if heavier cathode material capable of eight hours operation were used. There was little apparent difference in activation depending on the alloy used for the anode.

(b) Output Voltage:

The mid-point voltages listed in Table IV are within the specifications, however at 0° batteries made with AZ31 showed marginal output. This contributed to low cathode utilization since voltages dropped below 9.70 volts well before most of the active cathode material had been used. In general the AZ61 alloy give higher output voltage than AZ31.

TABLE IV

Constant Load Discharge of Ten Cell Mg/PbCl$_2$ Batteries

TEMP	SALINITY	ANODE	FUSE OPEN	DISCHARGE TIME TO 9.6V	MID-POINT VOLTAGE	CATHODE UTILIZATION	ENERGY DENSITY	THEORETICAL CAPACITY
deg.C	% NaCl	MgAlloy	S.	h.	volts	%	Whkg^{-1}	Ah
0°a*	1.5	AZ61	47	5.33	9.9	82	41	2.25
0°b*	1.5	AZ31	59	5.26	9.7	71	43	2.54
0°*	3.5	AZ61	30	5.35	10.0	96	44	1.93
0°*	3.5	AZ31	34	5.00	9.6	66	38	2.51
12°	1.5	AZ61	16	6.15	10.3	95	55	2.30
12°	3.5	AZ61	10	6.03	10.3	84	52	2.55
12°	3.5	AZ31	10	6.00	10.0	79	50	2.62
12°c	3.5	AZ61	12	5.88	10.0	77	49	2.64
12°c	3.5	AZ31	12	5.58	10.0	74	46	2.60
20°	1.5	AZ61	14	6.00	10.5	92	55	2.37
20°	3.6	AZ61	10	4.27	10.6	92	39	1.70
35°**	1.5	AZ61	12	4.95	10.8	86	48	2.14
35°**	1.5	AZ31	12	4.93	10.4	70	44	2.53
35°**	3.6	AZ61	9	5.10	10.8	90	49	2.10
35°**	3.6	AZ31	8	5.08	10.4	70	45	2.59

* Battery equilibrated at $-20°C$ before discharge.

** Battery equilibrated at $35°C$ before discharge.

a. Average of 3 experiments.

b. Average of 2 experiments.

c. Discharged after a 10 day humid storage.

(c) Length of Discharge:

     Clearly the cathode did not have sufficient capacity for eight hours of discharge. About twice the lead chloride content would be required; rather than 2.2 Ah the theoretical capacity should be approximately 4 Ah. Some batteries were able to exceed eight hours, but their activation fell below that specified (i.e. 60 seconds) at low temperature and low salinity. Two examples of this are presented below in Table V.

TABLE V

Examples of Eleven-Cell Batteries
Discharged for More than Eight Hours

	EXAMPLE 1	EXAMPLE 2
Theoretical Capacity (Ah)	4.94	4.98
Cathode Loading ($mgcm^{-2}$)	406	410
Electrolyte Temp/Salinity	$12^{o}C/3.6\%$	$0^{o}C/1.5\%$
Battery Temp. Before Discharge	$25^{o}C$	$-20^{o}C$
Activation Time (sec.)	6	80
Mid-Point Voltage (volts)	10.9	10.2
Discharge Time (hr)	9.7	9.0

    In the two examples quoted above the cathode material was too heavily loaded to give acceptable activation as exemplified by the long activation time at 0° in 1.5% solution.

(d) Cathode Utilization:

     Good utilization of the active material depends on minimizing intercell shorting. By improving the technique of assembling batteries a significant increase in efficiency has been demonstrated over earlier work (5). The AZ31 anode generally gave lower utilization because voltage was lower. The results in Table IV are in agreement with the cell discharge data which indicated about 90% efficiency could be expected (cf. Table IV, data at 20°C in 3.6% electrolyte). These results show that with good technique for wrapping batteries most of the intercell shorting losses can be eliminated.

(e) Energy Density:

     Values quoted for energy density are relevant only within the
present study. There is some preference for the use of AZ61 alloy
due to its higher voltage characteristic. For an eight-hour battery,
where sludge formation might be more prominent, the AZ31 alloy could
be required. The commercially available, eight-hour lead chloride
battery apparently employs this magnesium alloy (7).

(f) Discharge After Humid Storage:

     The electrical behaviour of both batteries which were subjected
to humid storage cycling for ten days did not appear to be altered
significantly compared with other discharge results. Visual
inspection after the storage period detected no change in physical
appearance of the batteries. Each one gained 4.7 g in weight during
the storage, apparently due to absorption of water.

THE PROBLEM OF THE EIGHT HOUR ELECTRODE

     It has been determined in this evaluation that the AIRI electrode
material in its current state of development is a suitable cathode for sono-
buoy batteries from consideration of its electrical discharge performance.
Electrode material which satisfactorily meets activation requirements cannot
however achieve the goals set for an eight-hour battery. Conversely, batteries
which yield capacity in excess of eight hours operation fail to activate
with acceptable rapidity in the extremes of low temperature and low salinity.

     The main reason that the AIRI electrode has not met the requirement
for eight hours of discharge is because it has not been possible to obtain
heavy enough loading of material on a woven copper screen and still satisfy
the specification for rapid activation. If further development of the AIRI
method is anticipated it is recommended that other types of metal substrates
be examined. It has been suggested that expanded metal grids be used instead
of woven screen (4). Expanded metals provide more available volume than
woven screen of comparable weight per unit area. They are readily available
and less costly than the woven screen. During the last month of the AIRI
contract it was demonstrated that expanded copper could be used in the AIRI
process. Several specimens were produced; however the grids used were too
light to be capable of the loading needed for an eight-hour electrode. It
is believed that use of a coarser expanded copper grid would be wholly
adequate to provide an eight-hour electrode.

SUMMARY

        The initial objective of this work was to evaluate the AIRI flexible
electrode as a suitable cathode for an eight-hour sonobuoy battery. In order
to ensure that batteries would activate rapidly in seawater of low salinity
and low temperature only material having lead chloride content of no more
than approximately 220 mg cm^{-2} could be considered. It was therefore not
possible to attain the eight hours discharge endurance; however ten-cell
batteries performed very well in the five to six hour range at all temperatures
and salinities: 0°C to 35°C and 1.5% to 3.6%, respectively. By improving
the design of electrolyte porting and battery assembly significant increases
were obtained in the overall efficiency of cathode utilization. These
batteries yielded efficiencies between 75% and 95% depending on temperature
and salinity. There was no significant deterioration in performance after
a ten day humid storage.

        Experiments were also conducted to examine the performance of the
magnesium alloys AZ61 and AZ31. The electrical behavior of the AZ61 alloy
was marginally better giving higher voltage and consequently increased
cathode efficiencies in the low temperature tests.

        Based on the results of this evaluation it is suggested that
expanded metal should be employed rather than woven screen if the goal of
an eight-hour battery is to be achieved employing the AIRI electrode material.

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DOCUMENT CONTROL DATA – R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATING ACTIVITY	2a. DOCUMENT SECURITY CLASSIFICATION
DREO, NDHQ, Ottawa, Ontario K1A 0Z4	UNCLASSIFIED
	2b. GROUP N/A

3. DOCUMENT TITLE

⑥ The AIRI Fusion Cast Lead Chloride Electrode. Part II. Evaluation of the Cathode for an Eight Hour Sonobuoy Battery.

DESCRIPTIVE NOTES (Type of report and inclusive dates)

⑨ Technical Note.   ⑭ DREO-TN-78-3

5. AUTHOR S (Last name, first name, middle initial)

⑯ Donaldson, George J. and Barnes, William D. /Barnes

6. DOCUMENT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
FEBRUARY 1978	19	7

8a. PROJECT OR GRANT NO.	9a. ORIGINATOR'S DOCUMENT NUMBER(S)
54-03-07 ⑪ Apr 78	DREO TECHNICAL NOTE NO. 78-3
8b. CONTRACT NO. ⑫ 26p.	9b. OTHER DOCUMENT NO.(S) (Any other numbers that may be assigned this document)

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The AIRI lead chloride cathode was evaluated for an eight hour sono-
buoy battery application. Tests on ten cell batteries resulted in only five
to six hours of discharge for electrodes capable of meeting the rigorous
activation criteria in low temperature, low salinity seawater. Cathodic
efficiencies between 75% and 95% were obtained and no deterioration in
electrical performance was detected as a result of a ten day humid storage
period. To achieve the goal of eight hours discharge it is recommended that
the AIRI cathode be fabricated using an expanded metal rather than a woven
screen.

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KEY WORDS

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